CRANIOFACIAL ANTHROPOMETRY: THE COMPARISON OF ACCURACY BETWEEN LASER SCANNING AND PHOTOGRAMMETRY TECHNIQUES

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ABSTRACT

Modelling and measuring of human face are increasingly becoming important for various purposes. One of the purposes is craniofacial anthropometry or human face measurement. Recent innovations in technology have generated a variety of techniques that can be used for craniofacial anthropometry purposes. In this paper, the accuracy of two different techniques was evaluated and compared between each others. The two techniques used in this paper were laser scanning and photogrammetric. Mannequin is the type of data used in this study. The mannequin was scanned using two laser scanners VIVID910 to create the 3D model. Then the measurement was made on the 3D model based on anthropometric landmarks. For photogrammetric technique, Sony Cybershot DSC F828 camera was used with AUSTRALIS software to make the measurements based on anthropometric landmarks. The results from both techniques then were evaluated and compared. From this study, we indicate that the measurement differences for both techniques are less than 1mm.

Keywords: craniofacial, anthropometric landmarks, laser scanning, photogrammetric

1.0 INTRODUCTION

Craniofacial (or simply human face) is an important part of human anatomy. Human face is a complex surface, with different depth and texture. In craniofacial anthropometry, human faces need to be modelled and measured accurately. Most surgeons are still relying on laborious traditional contact method (for example, calipers) for measuring anthropometric landmarks on human face. However this traditional method only give the information in 2-dimensional and it is difficult to understand the three-dimensional (3D) configuration of human face. As the results of the lack of 3D information obtained using traditional method, several methods and instruments (e.g. CT-Scan or MRI) are required to record the complex 3D surface structures of the human face.

3D recording and visualization of different anatomical structures is possible by means of computed tomography (CT-Scan) or magnetic resonance tomography (MRI). These tools, however, necessitate costly, elaborate, and sometimes invasive examinations. Especially in aesthetic, plastic, and reconstructive surgery, examination methods that can record 3D changes of body surface structures precisely, rapidly, and without side effects or major inconvenience for the patient would be of great benefit. Further, it would be desirable to measure body form with the patient standing, thus better accounting for the influence of gravitational forces (Kovacs *et al*, 2006).

In recent years, scanners have been developed for industrial uses (e.g. for engineering and the clothing and fashion industries), that have been successfully employed in monitoring, evaluation, and planning of 3D object surfaces. In medicine, 3D recording and visualization of the body surface could lead to a better understanding of anatomical structures and, thus, to an improvement of surgery planning and therapy. Surface scanners could also contribute to a more accurate assessment of human morphology. Advancement in technology has meant that these laser-scanning devices are now smaller and can be assembled in any location for studies on facial morphology. This, however, requires the systems to be carefully evaluated and validated before use in field settings. In our previous study (Kamil *et al*, 2006), a measurement comparison between contact method and laser scanning method was done. We found that the differences between contact method vs laser scanning method are between -0.7mm to 0.7mm.

2.0 METHOD

In this study, we evaluated and compared the measurements obtained using laser scanning method with another non-contact method which is close-range photogrammetry. For laser scanning method, the measurements were recorded using Konica Minolta VIVID910 and for close-range photogrammetric method, the Sony Cybershot DSC F828 was used along with AUSTRALIS software. Figure 1 shows the instruments used in this study.

Figure 1. VIVID910 Laser Scanner, Sony Cybershot DSC F828

The mannequin was mark with the craniofacial landmarks (Figure 2) on it surface to make the digitizing process much easier. A total 34 points of craniofacial landmarks were marked on the mannequin surface. Table 1 describes the definition for all craniofacial landmarks used in this study.

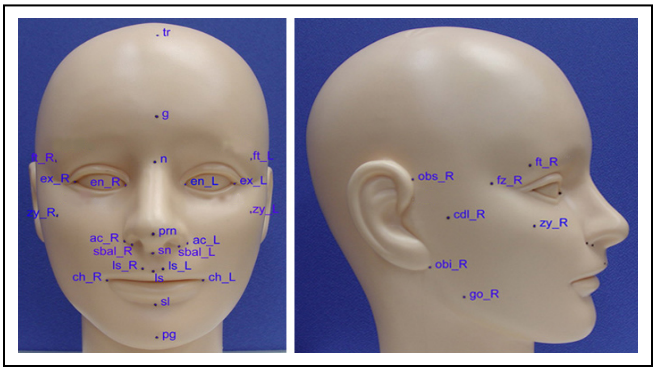

Figure 2. Position of the landmarks

2.1 Laser Scanning

The laser scanner used in this study is the Konica Minolta VIVID910. VIVID910 laser scanner system uses a laser beam to measure an object, and has the capability to record the whole measurement in a snap (about 0.3 sec (fast mode), 2.5 sec (fine mode), and 0.5 sec (color mode)). This apparatus employs the light-stripe method that emits a horizontal stripe laser to the object and scans it by a galvanic mirror. There are 3 main advantages of VIVID910, i.e. speed, precision, and simplicity (i.e. point and shoot simplicity for consistently excellent results). The accuracy (Z, typically) of laser scanner are within 0.008 mm using fine mode. VIVID910 employs 3 removable lenses with different focal distances, depending on the object sizes and measurement distances. VIVID910 comes with Polygon Editing Tool (P.E.T) software for real time scanning and data processing.

Table 1. Summary of Landmarks Definition on Craniofacial Surface

No	Landmark name	Initial	Description
1	Frontotemporale	ft	The most medial point on the temporal crest of the frontal bone
2	Frontozygomaticus	fz	The most lateral point on the frontozygomatic suture
3	Glabella	g	The most prominent point in the median sagital plane between the supraorbital ridges
4	Trichion	tr	Midpoint of the hairline
5	Condylion laterale	cdl	The most lateral point on the mandibular condyle
6	Gonion	go	The most lateral point at the angle of the mandible
7	Nasion	n	The midpoint of the nasofrontal suture
8	Pogonion	pg	The most anterior point in the middle of the soft tissue chin
9	Sublabiale	sl	The midpoint of the labiomental sulcus
10	Subnasale	sn	The junction between the lower border of the nasal septum, the partition which divides the nostrils, and the cutaneous portion of the upper lip in the midline
11	Zygion	zy	The most lateral point on the zygomatic arch
12	Endochantion	en	The inner corner of the eye fissure where the eyelids meet, not the caruncles (the red eminences at the medial angles of the eyes)
13	Exochantian	ex	The outer corner of the eye fissure where the eyelids meet
14	Alar curvature	ac	The most posterolateral point of the curvature of the base of the nasal alae, the lateral flaring walls of the nostrils
15	Pronasale	prn	The most protruded point of the nasal tip
16	Subalare	sbal	The point on the lower margin of the base of the nasal ala where the ala disappears into the upper lip skin
17	Cheilion	ch	The outer corner of the mouth where the outer edges of the upper and lower vermilions meet
18	Labial superius	ls	The midpoint of the vermilion border of the upper lip
19	Labiale superius lateralis	ls’	The point on the upper vermilion border directly inferior to subalare (sbal)
20	Otobasion inferius	obi	The lowest point of attachment of the external ear to the head
21	Otobasion superius	obs	The highest point of attachment of the external ear to the head

In this study, two VIVID910 were setup 1.0 meter from the mannequin and both scanners were setup at an angle of 60 degree (Figure 3). Both scanners were controlled using a P.E.T software and image from both scanners are shown side-by-side on the monitor. The scanning process was performed one after another.

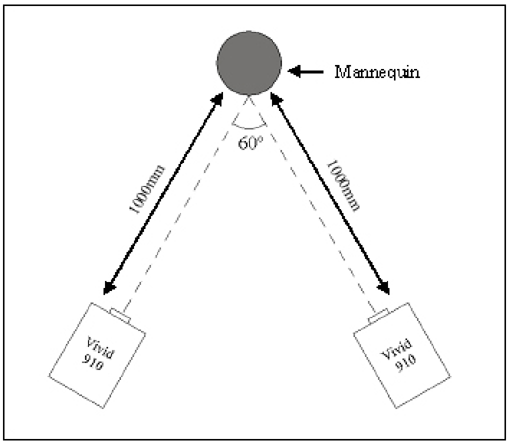

Figure 3. The setup of the laser scanning system

The scanner camera shots then were computed into a single, 3D, virtual image of the mannequin via RapidForm2004 software. Using the RapidForm software tools, a single recordings shot was merged to a final 3D model. This process, also called registration, uses the “interactive closest point (ICP) ” algorithm (Besl & McKay, 1992). In the registration process, at least three corresponding points was measured manually on the left and the right shell respectively. After digitizing the three points, the registration proceeded automatically. The final step in the processing of the scans is the 3D merging process. The merging process involves combining the two overlapping shells into one complete 3D surface model (Figure 4). Then the measurement can be done on the complete 3D surface model using point-to-point distance measurement function in the RapidForm software tools.

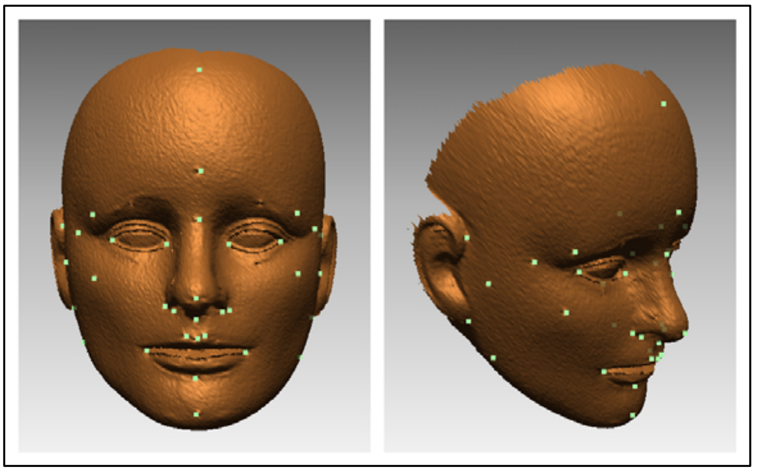

Figure 4. Complete 3D Model of Mannequin

2.2 Close-range Photogrammetry

In the close-range photogrammetry technique, a Sony Cybershot DSC F828 was used along with AUSTRALIS photogrammetric software to obtained the craniofacial measurements of the mannequin. The AUSTRALIS software is designed to perform highly automated image-based 3D coordinate measurements from digital images recorded with either professional semi-metric digital SLR cameras or consumer-grade cameras. It is equally useful for fully automatic measurement of targeted objects to high accuracy or for low-to-moderate accuracy semi-automatic or manual measurements in photogrammetric networks comprising natural feature points and images from off-the-shelf cameras.

A control frame was built to provide an accurate control for the research. Retro-targets were used to highlight the control points on the control frame. The x, y and z coordinates of the targets were determined using convergent photographs and a bundle adjustment. The coordinates would be used for computing craniofacial landmarks coordinates. Using the convergent method (Figure 5), six convergent photographs of the mannequin were captured. The camera lens to object distance was set to 600mm. A scale bar which consists of an invar bar with target at each ends, was placed in the object space.

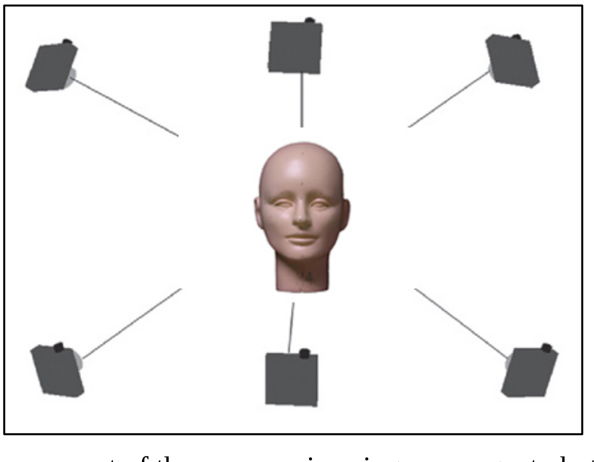

Figure 5. Measurement of the mannequin using convergent photogrammetric method

AUSTRALIS software was used to mono-digitise image coordinate (x, y and z) of the retro-targets on the control frame and craniofacial landmarks on the six convergent photographs. Retro-target on the scale bar were also digitized. A bundle adjustment was performed on the image coordinates of the digitized points using AUSTRALIS. The scale bar was used in the adjustment to scale the object-space coordinates. The output of the adjustment is a set of accurate coordinates for the control and craniofacial landmarks.

3.0 RESULTS AND ANALYSIS

The results are summarized in Tables 2 and 3. Table 2 shows the slope distance measurement using three different methods. In this study, measurements obtained by caliper was selected as a gold standard. A total 33 measurements were measured using each instrument on the same mannequin.

Table 2. Slope distance measurement (mm)

No	Measurements	Caliper [A]	Laser Scanner [B]	Photogrammetry [C[
1	ftR - ftL	93.955	94.246	93.974
2	tr - g	50.740	51.052	50.817
3	tr - n	70.865	71.034	70.970
4	fzR - fzL	112.660	112.748	112.912
5	fzR - g	73.455	73.267	73.789
6	fzL - g	71.960	71.218	72.176
7	zyR - zyL	93.340	93.302	93.379
8	goR - goL	107.225	107.252	107.516
9	exR - goR	61.570	60.873	61.212
10	exL - goL	66.220	66.340	66.040
11	goR - cdlR	39.610	39.851	39.635
12	goL - cdlL	41.880	42.201	42.227
13	g - sn	64.485	64.811	64.561
14	sn - pg	42.795	42.846	42.891
15	sl - pg	16.110	15.753	16.110
16	g - pg	106.510	107.004	106.713
17	enR - enL	27.620	27.645	27.864
18	exR - exL	76.765	76.916	76.992
19	enR - exR	26.380	26.676	26.334
20	enL - exL	24.955	25.185	24.905
21	sbalR - sn	11.425	11.278	11.473
22	sbalL - sn	12.820	12.367	12.630
23	sn - prn	15.935	15.954	15.491
24	acR - prn	24.405	24.539	24.283
25	acL - prn	26.020	25.914	25.942
26	n - sn	43.225	43.611	43.251
27	n - prn	38.000	38.133	37.820
28	chR - chL	44.250	43.978	44.474
29	sn - ls	8.380	8.479	8.622
30	sbalR - lsR	13.090	13.160	12.983
31	sbalL - lsL	13.665	13.409	13.483
32	obsR - obiR	42.190	42.594	42.258
33	obsL - obiL	42.165	42.325	42.363

Table 3 shows the comparison of the measurement between the caliper, laser scanner and photogrammetry. The differences between caliper vs. laser scanner (difference 1 in Table 3) are between (–0.7 mm to 0.5mm), caliper vs. photogrammetry (difference 2 in Table 3) and photogrammetry vs. laser scanner (difference 3 in Table 3) are between (–0.4mm to 0.4mm) and (–0.5mm to 1.0mm) respectively.

Further analysis was carried out using the mean, variance and standard deviation of the measurement difference. As shown in Table 3, we found that the measurement obtained by photogrammetry technique is better compared with laser scanner. However, the measurement obtained by laser scanner still gives a good results. The accuracy of this two techniques was proved by comparing it with gold standard measurements.

Table 3. Distance measurement differences (mm)

No	Measurements	Diff 1 [B - A]	Diff 2 [C - A]	Diff 3 [C - B]
1	ftR - ftL	0.291	0.019	-0.272
2	tr - g	0.312	0.077	-0.235
3	tr - n	0.169	0.105	-0.063
4	fzR - fzL	0.088	0.252	0.164
5	fzR - g	-0.188	0.334	0.522
6	fzL - g	-0.742	0.216	0.959
7	zyR - zyL	-0.038	0.039	0.077
8	goR - goL	0.026	0.291	0.264
9	exR - goR	-0.697	-0.358	0.340
10	exL - goL	0.120	-0.180	-0.300
11	goR - cdlR	0.241	0.025	-0.216
12	goL - cdlL	0.321	0.347	0.026
13	g - sn	0.326	0.076	-0.250
14	sn - pg	0.051	0.096	0.045
15	sl - pg	-0.357	0.000	0.357
16	g - pg	0.494	0.203	-0.292
17	enR - enL	0.025	0.244	0.219
18	exR - exL	0.151	0.227	0.076
19	enR - exR	0.296	-0.046	-0.342
20	enL - exL	0.230	-0.050	-0.280
21	sbalR - sn	-0.147	0.048	0.195
22	sbalL - sn	-0.453	-0.190	0.263
23	sn - prn	0.019	-0.444	-0.463
24	acR - prn	0.134	-0.122	-0.256
25	acL - prn	-0.106	-0.078	0.028
26	n - sn	0.386	0.026	-0.360
27	n - prn	0.133	-0.180	-0.313
28	chR - chL	-0.273	0.224	0.496
29	sn - ls	0.099	0.242	0.143
30	sbalR - lsR	0.070	-0.108	-0.177
31	sbalL - lsL	-0.256	-0.182	0.074
32	obsR - obiR	0.404	0.068	-0.336
33	obsL - obiL	0.160	0.198	0.038
	Mean	**0.236**	**0.160**	**0.256**
	Variance	**0.032**	**0.013**	**0.034**
	Std Dev	**0.180**	**0.114**	**0.184**

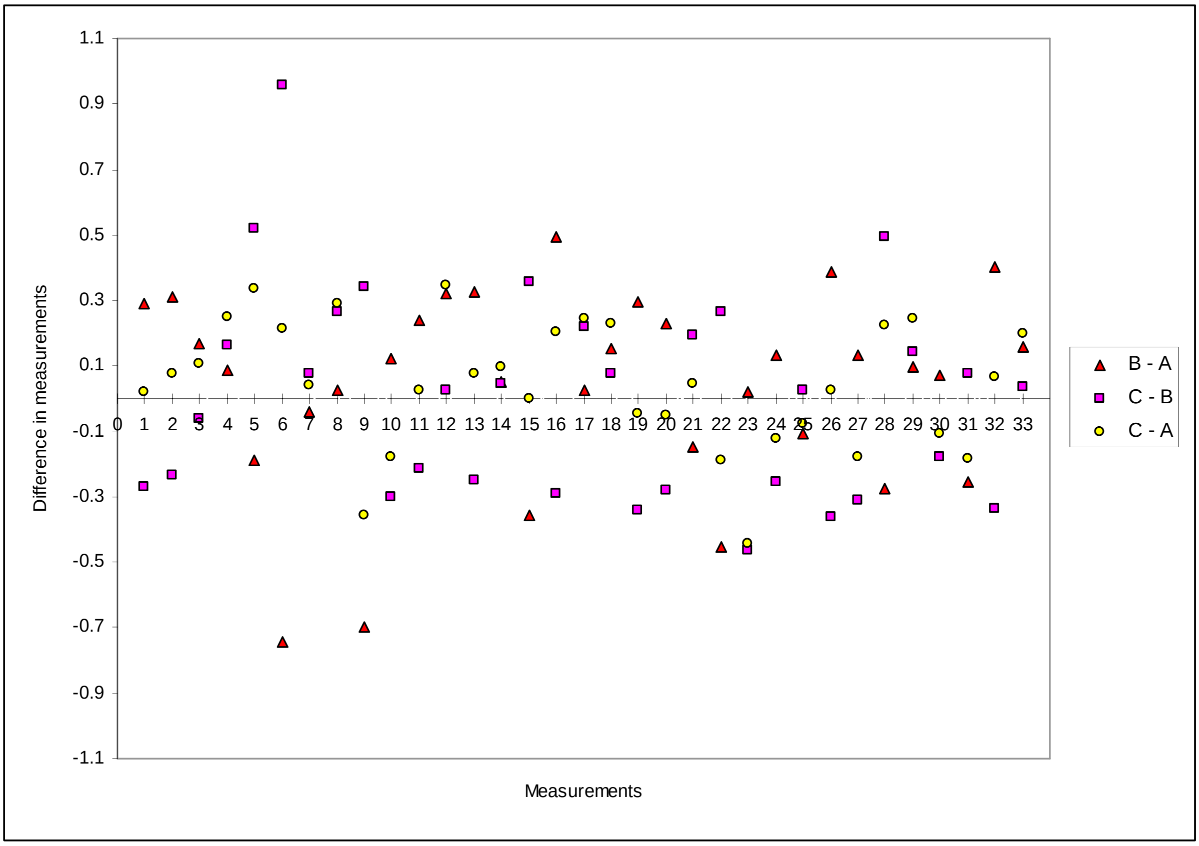

Figure 6. Difference in measurements (mm)

4.0 DISCUSSION AND CONCLUSION

Exact documentation of areas of the human face necessitates 3D imaging. A method that enhances objectivity in quantifying changes of form and volume of the face following surgery could become a valuable instrument in evaluating postoperative outcome. Different surgical techniques could be compared more easily in terms of their results and correct indications. Moreover, such a tool could be of great benefit in quality control in assessing asymmetry of the face.

In our study, we evaluated the comparison of the measurements obtained using two non-contact methods (i.e. laser scanning & close-range photogrammetry). The scanning object (mannequin) was scanned using two laser scanner and the data was merged into a single 3D model. From this 3D model, a series of measurements was done and was compared with the measurement obtained by photogrammetry technique.

Both laser scanning & close-range photogrammetry techniques show excellent results when compared with gold standard (caliper), and the differences are less than 1mm. Since the laser scanner and close-range photogrammetry is based on non-contact method, the 1mm different is satisfies in craniofacial application. This study also shows that the laser scanning method has great potential in the capturing and measurement of the 3D model of human face.

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